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(54) Title: CRACK RESISTANT SHELL MOLD AND METHOD

(57) Abstract: A method of making ceramic shell molds for investment casting includes repeatedly coating a fugitive pattern of the article to be cast with ceramic slurry layers and stuccoing the respective ceramic slurry layers with ceramic stucco wherein one or more of the ceramic slurry layers includes discontinuous needle shaped ceramic fibers in an amount effective to reduce shell mold splitting during a subsequent pattern removal operation.

CRACK RESISTANT SHELL MOLD AND METHOD

FIELD OF THE INVENTION

The present invention relates to ceramic investment shell molds for casting molten metals and alloys and, more particularly, to ceramic shell molds that are more resistant to cracking during the removal of a fugitive pattern from the shell mold.

BACKGROUND OF THE INVENTION

Both the investment casting process and the lost wax shell mold building process are well known, for example, as is apparent from the Operhall US Patents 3 196 506 and 2 961 751. The lost wax shell-mold building process involves repeatedly dipping a wax or other fugitive pattern of the article to be cast in ceramic slurry, draining excess slurry, and then stuccoing the slurry with coarse ceramic particles to build up a shell mold of desired wall thickness on the pattern. The green shell mold/pattern assembly then is subjected to a pattern removal operation to selectively remove the pattern from the shell mold. A commonly used wax pattern removal technique involves flash dewaxing where the green shell mold/pattern assembly is placed in an oven at elevated temperature to rapidly melt the wax pattern from the green shell mold. Following pattern removal, the green shell mold is fired at elevated temperature to develop mold strength for casting of molten metal or alloy therein.

During the pattern removal operation, the green shell mold can experience mold splitting or cracking as a result of stresses imparted to the shell mold by the heated wax pattern. Shell mold splitting is costly in that split molds are usually

discarded and not used in the investment casting operation. A previously developed lost wax shell mold building process involved stuccoing a plurality of the ceramic slurry layers with discontinuous fused needle mullite fiber stucco to reduce mold splitting.

An object of the present invention is to provide a method for making ceramic shell molds and shell molds so made using one or more ceramic fiber-containing ceramic slurry layers in a manner that reduces shell mold splitting, particularly during the pattern removal operation where the green shell mold is subjected to stresses from the heated fugitive pattern.

SUMMARY OF THE INVENTION

The present invention involves a method of making ceramic shell molds for investment casting including repeatedly coating a fugitive pattern of the article cast with ceramic slurry to form a plurality of ceramic slurry layers and stuccoing the ceramic slurry layers with ceramic stucco particles to form a plurality of stucco layers wherein at least one of the ceramic slurry layers includes discontinuous needle shaped (acicular) ceramic fibers in small amounts effective to unexpectedly and significantly reduce shell mold splitting during a subsequent pattern removal operation. The discontinuous needle shaped ceramic fibers typically are present in small amounts of 0.5 to 5 volume % of the ceramic slurry to this end. The discontinuous needle shaped ceramic fibers typically have an aspect ratio (fiber length to diameter) of 3:1 or greater to this end.

For example, in accordance with an illustrative embodiment of the invention, two or more ceramic slurry layers preferably include the needle shaped ceramic fibers, such as discontinuous

alumina fibers, in small amounts from about 0.5 to about 3 volume % of each ceramic slurry. One or more stucco layers may include needle shaped ceramic stucco fibers, such as discontinuous fused needle mullite fibers, in amounts up to 100 volume % of each stucco layer.

Green shell molds pursuant to the invention are tougher (more resistant to cracking) in a manner that reduces mold splitting during the pattern removal operation. However, strength of the fired molds is not appreciably increased to an extent that will cause cracking of a metallic casting solidified in the fired mold.

The above objects and advantages of the present invention will become more readily apparent from the following detailed description.

DETAILED DESCRIPTION OF THE INVENTION

The Examples set forth below are offered to further illustrate the lost wax ceramic shell mold building process to which the invention is applicable where a ceramic shell mold is formed by repeatedly coating a fugitive pattern of the article cast with ceramic slurry (i.e. ceramic flour in a liquid binder) described in the Examples, draining excess slurry, and then stuccoing the slurry with ceramic stucco particles to reduce shell mold splitting during a subsequent pattern removal operation. In the Examples, a conventional wax pattern of the article to be cast was subjected to the lost wax mold building process using the described ceramic slurries and stuccoes. The invention is not limited to wax fugitive patterns and can be practiced using other fugitive patterns, such patterns made of thermoplastics, polystyrene, wax/polymer blends and the like

that are removable from the green shell mold using conventional pattern treatments to selectively melt, leach and/or vaporize the pattern therefrom.

In the Examples, the prewet and ceramic slurries are described with respect to the particular ceramic flour or powder (e.g. alumina or zircon) and needle shaped ceramic fibers that were applied to the pattern. The prewet slurries and ceramic slurries comprise the particular ceramic flour mixed in a colloidal silica binder and were applied to the pattern by dipping the pattern in the slurry followed by draining of excess slurry. The dip # listed in the Examples corresponds to the first, second, third, etc., dip of the pattern in the listed slurry. The prewet slurries were applied for purposes of wetting previously applied sand or stucco layers. The alumina flour used in the Examples comprised -325 mesh (i.e. less than 325 mesh) commercially available alumina powder and about 50 volume % of each ceramic slurry. The zircon flour comprised -325 mesh commercially available zircon powder and about 45 volume % of each ceramic slurry. The discontinuous needle shaped (acicular) milled Saffil® fibers employed in the ceramic slurry dips pursuant to the invention as set forth in Examples 1, 2, and 5 comprised Saffil RFM 85 alumina fibers available from ICI Americas Inc., General Chemicals Dept., Concord Plaza, 3411 Silverside Road, Wilimington, Delaware 19850, and were milled (crushed) to provide at least 95% of the fibers with an aspect ratio (fiber length to fiber diameter) of 3:1 and greater. The discontinuous needle shaped alumina fibers were present in small amounts in volume % of the ceramic slurry as set forth, although the invention is not limited to the particular amounts set forth

in Examples 1, 2, and 5. The discontinuous needle shaped ceramic fibers can be present in small amounts from about 0.5 to about 5 volume %, preferably 0.5 to 3 volume %, of the slurry pursuant to the invention to reduce shell mold splitting. Discontinuous ceramic fibers other than, or in addition to, alumina fibers, such as alumino-silicate, silica and like fibers, can be included in the slurries in practicing the invention. The discontinuous ceramic fibers can be monocrystalline, polycrystalline, or amorphous oxide fibers. Also, other fibers including, but not limited to, carbon containing fibers, metallic fibers, plastic fibers and natural fibers may be present with the above discontinuous ceramic fibers.

The prewet and ceramic slurries described in the Examples also comprised conventional additives for green strength, wetting, and foam reduction, all of which additives are well known to those skilled in the art.

The ceramic stuccoes included commercially available fused or tabular alumina or fused needle mullite having the particle mesh sizes listed that were applied from a conventional stucco drop tower to each wet slurry layer after excess slurry is drained from the pattern. The fused alumina and tabular alumina stucco had a blocky particle morphology regardless of mesh size. The discontinuous needle shaped (acicular) fused mullite fibers employed in the stucco layers were available from Geral de Electrofusao Ltda. and distributed in the United States by U.S. Electrofused Minerals, Inc. The needle shaped fused mullite fibers had an aspect ratio (fiber length to fiber diameter) of 3:1 and greater.

Example 1

Dip #	Prewet	Slurry	Stucco
1	---	Alumina	120 Mesh Fused Alumina
2	Zircon	Zircon	90 Mesh Fused Alumina
3	Zircon	Zircon	28 x 48 Mesh Tabular Alumina
4	---	Zircon with 1.5% Milled Saffil	14 x 28 Mesh Tabular Alumina
5	---	Zircon with 1.5% Milled Saffil	14 x 28 Mesh Tabular Alumina
6	---	Zircon with 1.5% Milled Saffil	14 x 28 Mesh Tabular Alumina
7	---	Zircon with 1.5% Milled Saffil	14 x 28 Mesh Tabular Alumina
8	---	Zircon with 1.5% Milled Saffil	---

Example 2

Dip #	Prewet	Slurry	Stucco
1	---	Alumina	120 Mesh Fused Alumina
2	Zircon	Zircon	90 Mesh Fused Alumina
3	Zircon	Zircon	28 x 48 Mesh Tabular Alumina
4	---	Zircon with 1.0% Milled Saffil	14 x 28 Mesh Tabular Alumina
5	---	Zircon	14 x 28 Mesh Tabular Alumina
6	---	Zircon with 1.0% Milled Saffil	14 x 28 Mesh Tabular Alumina
7	---	Zircon	14 x 28 Mesh Tabular Alumina
8	---	Zircon with 1.0% Milled Saffil	---

Example 3

Dip #	Prewet	Slurry	Stucco
1	---	Alumina	120 Mesh Fused Alumina
2	Zircon	Zircon	90 Mesh Fused Alumina
3	Zircon	Zircon	30/50 Fused Needle Mullite
4	---	Zircon	16/30 Fused Needle Mullite
5	---	Zircon	16/30 Fused Needle Mullite
6	---	Zircon	16/30 Fused Needle Mullite
7	---	Zircon	16/30 Fused Needle Mullite
8	---	Zircon	---

Example 4

Dip #	Prewet	Slurry	Stucco
1	---	Alumina	120 Mesh Fused Alumina
2	Zircon	Zircon	70 Mesh Fused Alumina
3	Zircon	Zircon	30/50 Fused Needle Mullite
4	---	Zircon	16/30 Fused Needle Mullite
5	---	Zircon	14 x 28 Mesh Tabular Alumina
6	---	Zircon	16/30 Fused Needle Mullite
7	---	Zircon	14 x 28 Mesh Tabular Alumina
8	---	Zircon	---

Example 5

Dip #	Prewet	Slurry	Stucco
1	---	Alumina	120 Mesh Fused Alumina
2	Zircon	Zircon	90 Mesh Fused Alumina
3	Zircon	Zircon with 1.8% Milled Saffil	30/50 Fused Needle Mullite
4	---	Zircon with 1.8% Milled Saffil	16/30 Fused Needle Mullite
5	---	Zircon with 1.8% Milled Saffil	14 x 28 Mesh Tabular Alumina
6	---	Zircon with 1.8% Milled Saffil	14 x 28 Mesh Tabular Alumina
7	---	Zircon with 1.8% Milled Saffil	14 x 28 Mesh Tabular Alumina
8	---	Zircon with 1.8% Milled Saffil	---

Example 6

Dip #	Prewet	Slurry	Stucco
1	---	Alumina	120 Mesh Fused Alumina
2	Zircon	Zircon	90 Mesh Fused Alumina
3	Zircon	Zircon	30/50 Fused Needle Mullite
4	---	Zircon	16/30 Fused Needle Mullite
5	---	Zircon	14 x 28 Mesh Tabular Alumina
6	---	Zircon	14 x 28 Mesh Tabular Alumina
7	---	Zircon	14 x 28 Mesh Tabular Alumina
8	---	Zircon	---

Example 7

Dip #	Prewet	Slurry	Stucco
1	---	Alumina	120 Mesh Fused Alumina
2	Zircon	Zircon	90 Mesh Fused Alumina
3	Zircon	Zircon	28 x 48 Mesh Tabular Alumina
4	---	Zircon	14 x 28 Mesh Tabular Alumina
5	---	Zircon	14 x 28 Mesh Tabular Alumina
6	---	Zircon	14 x 28 Mesh Tabular Alumina
7	---	Zircon	14 x 28 Mesh Tabular Alumina
8	---	Zircon	---

In the Examples above, 28 x 48 mesh stucco means stucco particle size of less than 28 mesh and greater than 48 mesh, 14 x 28 stucco means stucco particle size of less than 14 mesh and greater than 28 mesh. Similarly, 30/50 stucco means stucco particle size of less than 30 mesh and greater than 50 mesh, and 16/30 stucco means stucco particle size of less than 16 mesh and greater than 30 mesh. Mesh sizes are with respect to U.S.

standard screen system.

Green shell molds made from the ceramic slurries and stuccoes set forth in Examples 1-6 in general had a mold wall thickness of about 0.25 inch. The green shell molds formed on the wax patterns were subjected to a pattern removal operation involving flash fire dewaxing and were visually examined for mold splitting or cracking.

Green shell molds formed using the slurries and stuccoes set forth in the Examples 1, 2, 5 pursuant to the invention exhibited substantially reduced mold splitting or cracking as compared to comparison shell molds similarly made without the discontinuous needle shaped fibers, see Example 7. Green shell molds formed using the slurries and stuccoes set forth in the Examples 3, 4, and 6 also exhibited substantially reduced mold splitting or cracking as compared to comparison shell molds similarly made without the discontinuous needle shaped fibers, see Example 7. For example, shell molds made pursuant to Examples 1, 2, 3, 4, 5, and 6 exhibited 0%, 4%, 0%, 4%, 0% and 4% split molds, respectively, as compared to 80% split molds for the comparison molds (Example 7) similarly made without the discontinuous needle shaped ceramic fibers in the ceramic slurry or stucco layers.

From Examples 1, 2, and 5 pursuant to the invention, it is apparent that use of the small amounts of the discontinuous needle shaped ceramic fibers (e.g. Saffil fibers) in the ceramic slurry layers set forth was effective to significantly reduce shell mold splitting. Example 5 included small amounts of the discontinuous needle shaped ceramic fibers (Saffil fibers) in the ceramic slurry layers set forth and also employed a fused

needle mullite stucco in the 3rd and 4th stucco layers to reduce shell mold splitting. The reduction in mold splitting was comparable to that achieved in Examples 3, 4, and 6. The green shell molds were tested for susceptibility to mold splitting by a split prone mold test which involved flash dewaxing at 1800 degrees F of unvented mold shells formed on round-end cylindrical wax patterns.

The present invention thus is effective to reduce mold splitting or cracking during pattern removal by incorporating discontinuous needle shaped ceramic fibers in the ceramic slurry layers in small amounts effective to this end. Incorporation of the ceramic fibers to this end did not significantly increase the strength of the high temperature fired shell mold (fired at 1800 degrees F). That is, the toughness (or resistance to splitting or cracking) of the green shell molds of the invention was increased without correspondingly increasing high temperature fired mold strength to an adverse extent that could cause cracking of a metallic castings solidified in the molds or difficulty in removing the shell mold after casting.

The incorporation of discontinuous ceramic fibers in the shell mold layers may likewise provide an increase in toughness of the mold during handling, preheat, and casting operations which helps to avoid mold cracks/splits during these operations as well.

Although the present invention has been described with respect to certain specific illustrative embodiments thereof, it is not so limited and can be modified and changed within the spirit and scope of the invention as set forth in the appended claims.

We Claim:

Claims

1. A method of making ceramic shell molds for investment casting, comprising repeatedly coating a fugitive pattern of an article to be cast with ceramic slurry layers and stuccoing the ceramic slurry layers with ceramic stucco to form a plurality of stucco layers wherein at least one of the ceramic slurry layers includes discontinuous needle shaped ceramic fibers in an amount effective to reduce shell mold splitting during a subsequent pattern removal operation.

2. The method of claim 1 wherein said needle shaped ceramic fibers have an aspect ratio of 3:1 and greater.

3. The method of claim 1 wherein said needle shaped ceramic fibers are present in amounts from about 0.5 to about 5 volume % of the ceramic slurry.

4. The method of claim 1 wherein said needle shaped ceramic fibers are present in amounts from about 0.5 to about 3 volume % of the ceramic slurry.

5. The method of claim 1 wherein two or more of said ceramic slurry layers include said discontinuous needle shaped ceramic fibers.

6. A shell mold for investment casting comprising a plurality of layers including ceramic flour and a plurality of ceramic stucco layers wherein at least one of said layers including said

ceramic flour also includes discontinuous needle shaped ceramic fibers in an amount effective to reduce shell mold splitting during a subsequent pattern removal operation.

7. The mold of claim 6 wherein said needle shaped ceramic fibers have an aspect ratio of 3:1 and greater.

8. The mold of claim 6 wherein two or more of the layers including said ceramic flour also include discontinuous needle shaped ceramic fibers.

9. The mold of claim 8 wherein said needle shaped ceramic fibers have an aspect ratio of 3:1 and greater.

INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :B22C 9/04
US CL :164/361, 516, 517, 519
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 164/361, 516, 517, 519

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WEST

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,712,435 A (FEAGIN) 27 January 1998, col. 11, lines 51-58.	1-9
Y	US 5,944,088 A (FEAGIN) 31 August 1999, col. 11, lines 48-55.	1-9

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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